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Evaluation of the proposed management plan of herring in VIaS, VIIbc

(STECF Plenary Meeting PLEN 13-01)

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Evaluation of the proposed management plan of herring in VIaS VIIbc
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Abstract

DGMARE requested that STECF evaluate the proposed management plan of herring in VIaS and VIIbc as part of the plenary meeting 13-01. The first Term of Reference was to assess the plan for compatibility with the Precautionary Approach and its ability to manage the stock to MSY by 2015. This was investigated using stochastic medium term forecasts, the methods and results of which are presented here. As noted in the STECF 2012 autumn plenary meeting, some points of the revised plan require clarification with the Pelagic RAC. The simulations were performed under several assumptions and with different scenarios: whether there continue to be overcatches (i.e. the total catch is greater than the TAC) and whether the TAC is allowed to be set to zero if the SSB falls below 76 kt.

The results suggest that the plan is able to maintain fishing mortality at levels below F_{msy}. However, the ability of the plan to allow the SSB to recover above B_{pa} depends on the level of overcatch (catch above the TAC) and whether the plan is allowed to reduce the TAC to zero if necessary. It is considered very unlikely that the SSB will recover to be above B_{pa} by 2015 for any of the scenarios evaluated. By 2020 the probability that SSB will be below B_{pa} ranges from 11 to 79% depending on the scenario. The least precautionary scenario is where overcatches continue and the TAC is not allowed to be set to zero.

Given the time available, it was not possible to execute all of the suggestions made by STECF during the 2012 autumn plenary meeting regarding a full evaluation of the revised plan. These forecasts are not equivalent to a full evaluation. For example, in the simulations no assessment is performed and the plan is executed assuming perfect knowledge of the stock status. This means that the results of the simulations should only be considered as exploratory.

Contents

1 Introduction

1.1 Background

In 2011 the Pelagic RAC (PRAC) proposed a plan for the manangement of herring in VIaS and VIIbc. The plan was examined by the Scientific, Technical and Economic Committee for Fisheries (STECF) during its 2011 autumn plenary meeting (STECF, 2011). Several comments were then issued concerning areas for improvement. Subsequently, the PRAC agreed to introuduce amendments to the proposed plan in order to take the feedback from STECF on board.

STECF, in its 2012 autumn plenary meeting, performed a preliminary evaluation of the plan and outlined the steps required for a full evaluation (STECF, 2012). These steps included agreeing a set of scenarios between stakeholders and scientists as well as considering the adaption of fishers behaviour and changes to revenues from following the plan. It was also recommended that PRAC work with whoever is to carry out the evaluation to ensure that each point of the plan has its intended changes.

In February 2013 a request was made for an evaluation of the plan. The Terms of Reference (ToR) were:

1. Assess the proposed management plan, as revised, for compatibility with the Precautionary Approach and its ability to drive to managment to this stock to MSY by 2015.
2. Specifically assess the desirability and expected efficiency of the measures forseen in point 6 of the plan in ensuring good management of the stock.

Here we address the first ToR. Given the time available, it was not possible to execute all of the suggestions made by STECF during the 2012 autumn plenary meeting regarding a full evaluation of the revised plan. As agreed with STECF, this ToR was dealt with by performing stochastic medium term forecasts. The methods and results of the forecasts are presented here.

1.2 The plan

The text of the revised plan is as follows:

1. Every effort shall be made to keep SSB above 76,000 t (SSB consistent with unacceptable risk of recruitment impairment).
2. For 2013 and subsequent years the TAC shall be set based on fishing mortalities, as follows:
    (a) $SSB \geq B_{pa}, F = F_{0.1}$
    (b) $SSB \leq B_{pa}, F = SSB * (F_{0.1}/B_{pa})$
3. If an assessment is available, but is considered by ICES to be less reliable, then the TAC settings in paragraph 2 shall apply, but the TAC shall be downweighted by a factor (G) based on the level of uncertainty. The parameter G is defined as folllows: $G = TAC * exp(-1.645 * \sigma)$, where σ refers to the standard deviation of the final year SSB estimate.
4. If ICES considers that SSB is at risk of being below 76,000 t, the TAC shall be based on ICES advice, and set at a lower level than provided for in Section 2.b.
5. In order to provide for separate management of this stock, relative to that in VIaN, every effort shall be made to disaggregate abundance-at-age data in Division VIa.
6. In order to avoid bycatches and unaccounted mortality of this stock, and in light of the problem of disaggregating stock-specific data, it is necessary to establish an interim temporary exclusion zone for 2 years. In anticipation of results of the analyses being conducted by ICES, and until better information on stock mixing is available, a temporary exclusion zone prohibiting herring fishing shall be established that lies between 56° N and 57°30 N, in Sub-Division VIaN. (It should be noted that this exclusion will only affect catches of herring by the Irish Fleet in VIaN)
7. When SSB is deemed to have recovered to a size equal to or greater than Bpa in three consecutive years, the rebuilding plan will be superseded by a long-term management plan.

1.3 Interpreting the plan

As mentioned by STECF in the autumn plenary 2012, a full evaluation of the plan requires the decision process to be translated into a harvest control rule (HCR) that can be described as a mathematical algorithm. As the plan currently stands, only Points 2 and 3 can be implemented using an HCR algorithm. Points 4, 5, 6 and 7 of the plan are therefore not considered in this evaluation. As mentioned by STECF in the 2012 autumn plenary meeting, Point 1 might be construed as reducing the catch to zero (in contrast to following Point 2). The impact of the plan allowing a zero TAC to be set is one of the scenarios investigated here.

1.4 Scenarios

Following the above discussion on the interpretation of the revised plan, here we consider the following HCR scenarios:

- Point 1 can be interpreted to mean that if SSB falls below 76 kt, the TAC can be set to zero.
- Whether to include overcatch or not, i.e. should the realised catch exactly equal the TAC.

Another scenario where the future fishing mortality is held constant at a level equal to the mean of the last three years is also performed (a 'status quo' scenario). This gives a total of five scenarios, including four that use the HCR:

1. No overcatch; TAC cannot be set to zero.
2. No overcatch; TAC can be set to zero.
3. With overcatch; TAC cannot be set to zero.
4. With overcatch; TAC can be set to zero.
5. Constant fishing mortality.

An additional scenario was considered which was whether or not the future stock assessments were considered by ICES to be unreliable (Point 3 in the plan). However, as we do not perform stock assesments in the projections and we therefore essentially assume that the HCR is being applied to perfect knowledge of the stock, this scenario was not appropriate here. It should be considered as part of the full evaluation within an MSE framework.

2 The projections

All the projections were carried out using FLR (Kell et al., 2007) and R (R Core Team, 2012).

```
library(FLCore)
library(FLAssess)
library(FLash)
library(ggplotFL)
library(mvtnorm)
library(plyr)
library(reshape)
library(xtable)
library(fields)
```

```
sessionInfo()
```

```
## R version 2.15.3 (2013-03-01)
## Platform: x86_64-pc-linux-gnu (64-bit)
##
## locale:
##  [1] LC_CTYPE=en_US.UTF-8       LC_NUMERIC=C
##  [3] LC_TIME=en_US.UTF-8        LC_COLLATE=en_US.UTF-8
##  [5] LC_MONETARY=en_US.UTF-8    LC_MESSAGES=en_US.UTF-8
##  [7] LC_PAPER=C                 LC_NAME=C
##  [9] LC_ADDRESS=C               LC_TELEPHONE=C
## [11] LC_MEASUREMENT=en_US.UTF-8 LC_IDENTIFICATION=C
##
## attached base packages:
## [1] grid      stats     graphics  grDevices utils     datasets  methods
## [8] base
##
## other attached packages:
##  [1] fields_6.7       spam_0.29-2      xtable_1.7-1     reshape_0.8.4
##  [5] plyr_1.8         mvtnorm_0.9-9994 ggplotFL_0.1     ggplot2_0.9.3.1
##  [9] FLash_2.5.0      FLAssess_2.5.0   FLCore_2.5.0     MASS_7.3-23
## [13] lattice_0.20-13  knitr_1.1        vimcom_0.9-7     setwidth_1.0-3
## [17] colorout_1.0-0
##
## loaded via a namespace (and not attached):
##  [1] colorspace_1.2-1   dichromat_2.0-0    digest_0.6.3
##  [4] evaluate_0.4.3     formatR_0.7        gtable_0.1.2
##  [7] labeling_0.1       munsell_0.4        proto_0.3-10
## [10] RColorBrewer_1.0-5 reshape2_1.2.2     scales_0.2.3
## [13] stats4_2.15.3      stringr_0.6.2      tcltk_2.15.3
## [16] tools_2.15.3
```

2.1 Initial population

There is no accepted assessment for the stock. The output from the 2012 exploratory ICA assessment (ICES, 2012) is used to set up the initial population (Figure 1). This gives stock information, including estimates of abundance and fishing mortality, up to the end of 2011:

```
# Load the ICA data
stock <- readFLStock("her-irlw/index.txt")
stock.n(stock) <- readVPAFile("her-irlw/n.txt")
harvest(stock) <- readVPAFile("her-irlw/f.txt")
# Tidy up and make consistent
landings(stock) <- computeLandings(stock)
# Assume no discards - see HAWG 2012 p 384
discards.wt(stock) <- landings.wt(stock)
discards.n(stock) <- 0
discards(stock) <- computeDiscards(stock)
# So catch = landings
catch.wt(stock) <- landings.wt(stock)
catch.n(stock) <- landings.n(stock)
catch(stock) <- computeCatch(stock)
# Units, Fbar and plus group
units(harvest(stock)) <- "f"
range(stock)[c("minfbar", "maxfbar")] <- c(3, 6)
stock <- setPlusGroup(stock, plusgroup = 7)
```

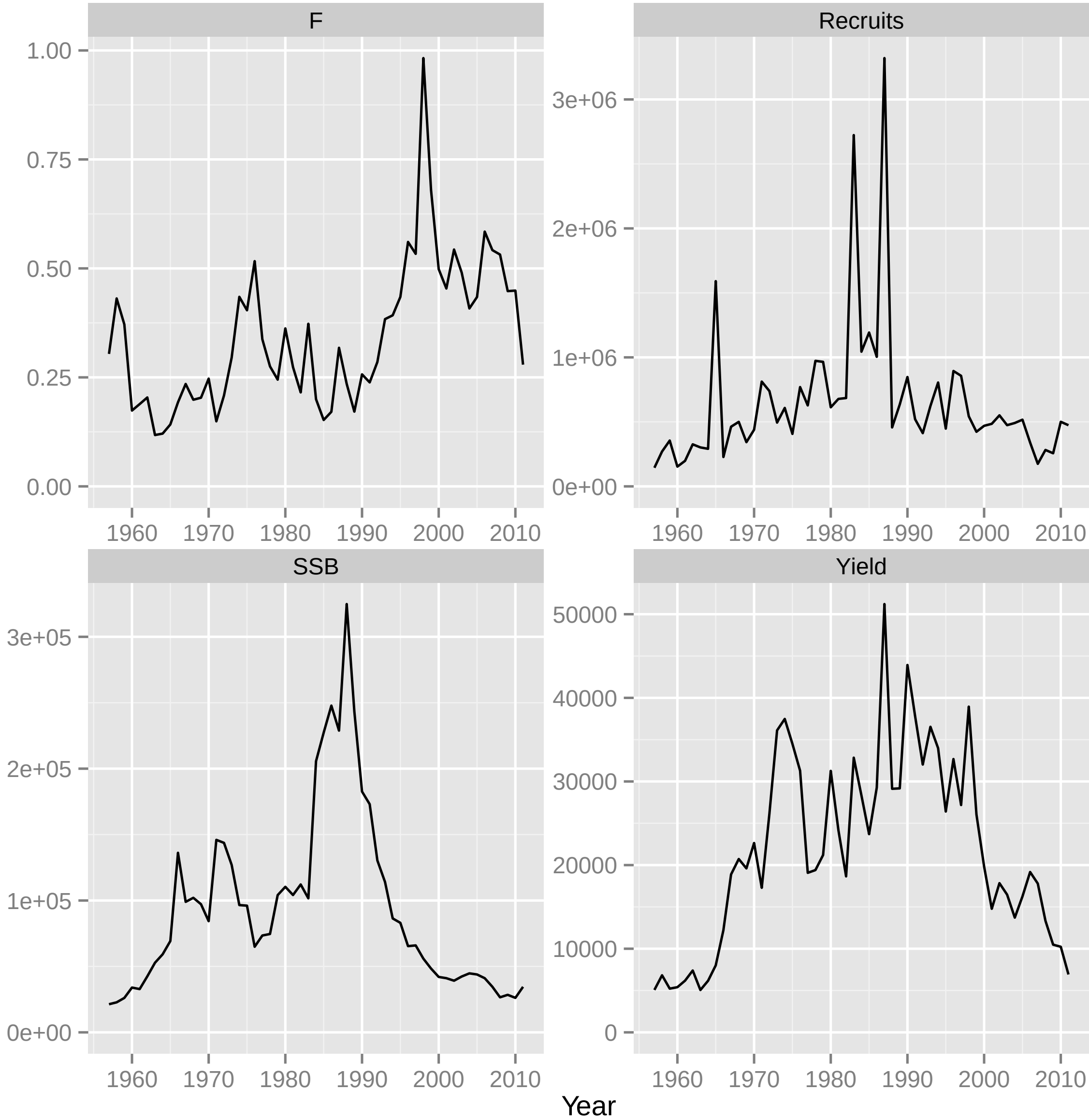

Figure 1: Results of the 2012 exploratory ICA assessment

2.2 The stock recruitment relationship (SRR)

One of the key drivers of the stock dynamics and growth rates is the stock-recruitment relationship (SRR). Here we use a Beverton-Holt relationship (Figure 2).

```
srr <- fmle(as.FLSR(stock, model = "bevholt"))
```

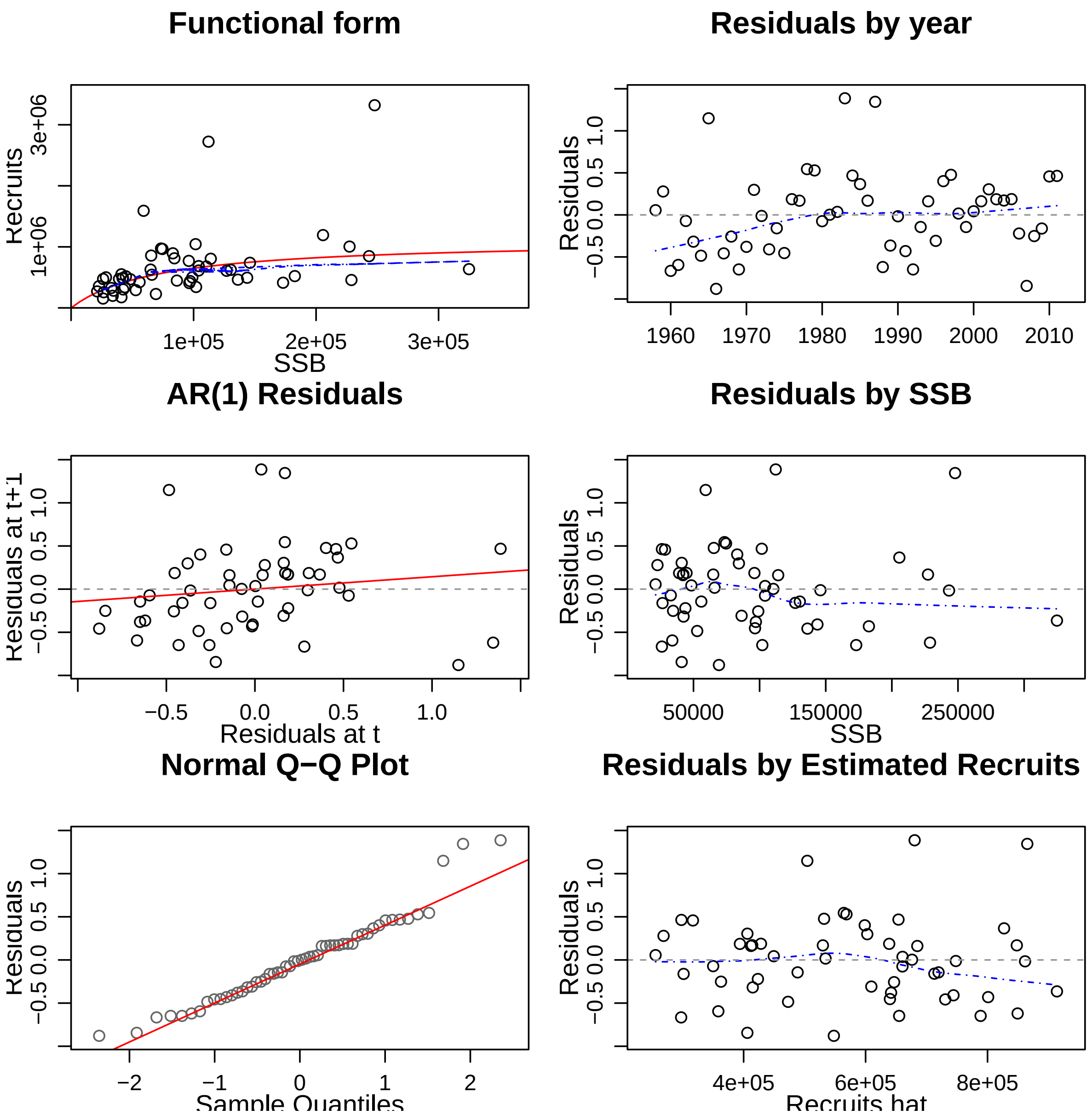

Figure 2: Results from fitting the Beverton-Holt stock-recruitment relationship

A plot of the log likelihood surface around the fitted parameters show that the surface is quite flat around the most likely estimates of a and b (1.1157×10^6 and 7.1757×10^4) (Figure 3). This indicates a lot of uncertainty in the fitted SRR. The a and b parameters are also correlated. To explore the impact of uncertainty in the SRR on the performance of the management plan, replicates are drawn from the SRR likelihood function using a basic accept / reject method (Gentle, 2002). The majorizing distribution is a multinormal distribution with a variance-covariance matrix based on the estimated variance-covariance matrix of the fitted SRR. The target density is taken to be proportional to the likelihood. A thousand replicates are taken.

```
niters <- 1000
```

```
# It is necessary to rescale and refit the SRR to make sure the var-covar
# matrix is accurate
srr_scale <- srr
rec(srr_scale) <- rec(srr_scale)/1000
ssb(srr_scale) <- ssb(srr_scale)/1000
```

```
srr_scale <- fmle(srr_scale)
# Simple acceptance / rejection px - target density gy - majorizing /
# proposal density Necessary condition: c gy(x) >= px(x) for all x Due to
# weird shape of likelihood surface we need to crank up the variance
# covariance matrix to make sure it covers the surface - fairly crude
vcov2 <- vcov(srr_scale)[, , 1] * 500
# Sort out c
max_px <- 1
max_ll <- srr_scale@logl(params(srr_scale)["a"], params(srr_scale)["b"], rec(srr_scale),
    ssb(srr_scale))
max_gy <- dmvnorm(c(params(srr_scale)["a"], params(srr_scale)["b"]), mean = c(params(srr_scale)["a"],
    params(srr_scale)["b"]), sigma = vcov2)
# c should be as small as possible
c <- (1/max_gy) + 1
# Is c * gy >= px?  Try an extreme point
amax <- params(srr_scale)["a"] * 20
bmax <- params(srr_scale)["b"] * 20
ll <- srr_scale@logl(amax, bmax, rec(srr_scale), ssb(srr_scale))
# rescale the likelihood so it goes from 0 to 1 - likelihood is now
# proportional to probability
px = exp(ll - max_ll)
gy <- dmvnorm(c(amax, bmax), mean = c(params(srr_scale)["a"], params(srr_scale)["b"]),
    sigma = vcov2)
# meet condition at the extreme?
gy * c > px
# Run the acceptance/rejection method in batches - takes some time
batch_size <- 200
good_points <- data.frame()
while (nrow(good_points) < niters) {
    y <- rmvnorm(batch_size, mean = c(params(srr_scale)["a"], params(srr_scale)["b"]),
        sigma = vcov2)
    # remove negative rows
    y <- y[(y[, 1] > 0) & (y[, 2] > 0), ]
    u <- runif(nrow(y))
    px <- numeric()
    # This for loop is the hold up - need to vectorise the logl function
    for (i in 1:nrow(y)) px[i] <- exp(srr_scale@logl(y[i, 1], y[i, 2], rec(srr_scale),
        ssb(srr_scale)) - max_ll)
    gy <- dmvnorm(y, mean = c(params(srr_scale)["a"], params(srr_scale)["b"]),
        sigma = vcov2)
    x <- ifelse(u <= (px/(c * gy)), TRUE, FALSE)
    good_points <- rbind(good_points, cbind(a = y[x, 1], b = y[x, 2]))
}
sr_replicates <- good_points * 1000
```

We can see the replicates are appropriately spread across the log likelihood surface (Figure 3). These replicates are then stored in the SRR object.

```
srr_iters <- srr
params(srr_iters) <- propagate(params(srr_iters), niters)
params(srr_iters)["a"] <- sr_replicates[, 1]
params(srr_iters)["b"] <- sr_replicates[, 2]
```

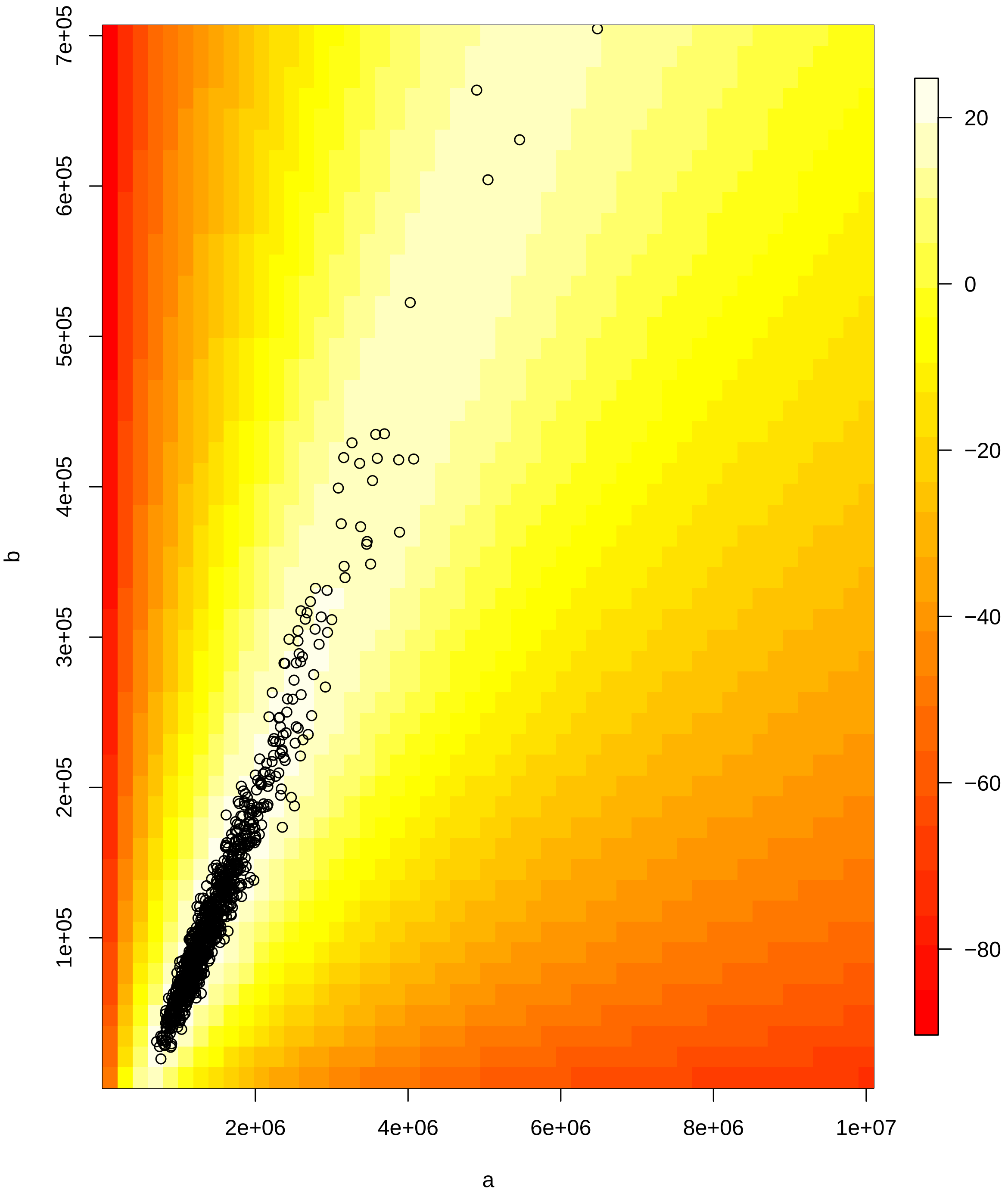

Figure 3: Stock-recruitment parameter replicates superimposed on the log likelihood surface

2.3 Model parameters

We set the reference points and TAC established by ICES (ICES, 2012):

```
tac_2012 <- 4247
bpa <- 110000
```

```
f01 <- 0.2
fmsy <- 0.25
blim <- 81000
bclause1 <- 76000  # From Point 1, SSB consistent with unacceptable risk of recruitment impairment
```

It is assumed that the future values of biological parameters (maturity, weights etc.) are the same as the mean of the last three years (2009 to 2011).

```
wts.nyears <- 3
fbar.nyears <- 3
```

2.4 Setting up the projections

To perform the projections we need to extend the stock object over the projection years. As we are running stochastic projections we also need to propagate the stock to store the stochastic iterations.

We use the estimated standard deviations of abundances from the ICA assessment to add noise to the stock abundances in 2011. The noise on the first age group is based on the predicted recruitment from the SRR with randomly selected residuals.

For the future projections, we use the SRR parameter replicates to include uncertainty on the SRR.

If we are running a scenario which includes overcatch (i.e. the TAC is not implemented perfectly) then we set up an FLQuant of overcatches. The values are taken from the STECF 2012 autumn plenary report (STECF, 2012) which estimated the mean and standard deviation of the overcatch. Here we assume that the overcatch is lognormally distributed so we need to transform the the mean and the standard deviation.

```
overcatch_bias <- 2400
overcatch_sd <- 1400
overcatch_sigma <- sqrt(log(1 + overcatch_sd^2/overcatch_bias^2))
overcatch_mu <- log(overcatch_bias) - 0.5 * overcatch_sigma^2
```

The TAC in 2012 has been set to 4247 t. This TAC may be subject to overfishing, depending on which scenario we are running. Additionally, the fishing mortality in 2011 has been estimated by the ICA assessment. From this information it is possible to calculate the estimated SSB at the start of 2013.

By putting all this into a function, we can estimate the stock at the start of 2013, based on the SRR and overcatch scenario we are running.

```
make_stock_proj <- function(stock, srr, niters = 1000, nyears = 19, overcatch_flag = FALSE) {
    # Set up projection stock
    stock_proj <- stf(stock, nyears = nyears, wts.nyears = wts.nyears, fbar.nyears = fbar.nyears)
    stock_proj <- propagate(stock_proj, iter = niters)
    # Noise on abundances at age in 2011 using SDs of ICA estimates
    assess_error = c(0.4809182, 0.3727776, 0.3582298, 0.3821252, 0.4199497,
        0.4199497)
    n_noise <- FLQuant(rlnorm(niters * length(assess_error), sdlog = assess_error),
        dim = c(length(assess_error), 1, 1, 1, 1, niters))
    stock.n(stock_proj)[2:7, "2011"] <- stock.n(stock_proj)[2:7, "2011"] * n_noise
    # Set recruitment in 2011 based on predicted from SRR plus residuals
    stock.n(stock_proj)[1, "2011"] <- c(predict(srr, ssb = iter(ssb(stock_proj)[,
        "2010"], 1))) * sample(exp(c(residuals(srr))), niters, replace = TRUE)

    # Overcatch
    overcatch <- FLQuant(NA, dimnames = list(year = 2012:(2012 + nyears - 1),
        iter = 1:niters))
```

```
    overcatch[] <- rlnorm(prod(dim(overcatch)), meanlog = overcatch_mu, sdlog = overcatch_sigma)
    # Check we've set that up correctly apply(overcatch,2,mean)
    # apply(overcatch,2,sd)

    # Project to start of 2013
    catch_2012 <- tac_2012
    if (overcatch_flag)
        catch_2012 <- tac_2012 + overcatch[, "2012"]
    ctrl <- fwdControl(data.frame(year = 2012, val = c(catch_2012)[1], quantity = "catch"))
    ctrl@trgtArray <- array(NA, dim = c(1, 3, niters), dimnames = list("2012",
        c("min", "val", "max"), iter = 1:niters))
    ctrl@trgtArray[1, 2, ] <- c(catch_2012)  # set the iterations
    stock_proj <- fwd(stock_proj, ctrl = ctrl, sr = srr_iters)

    return(list(stock_proj = stock_proj, overcatch = overcatch))
}
```

2.5 Implementing the HCR

The HCR implemented here is built around Point 2 of the revised plan. This calculates the value of the desired fishing mortality (F), given the current SSB. Here we assume that the HCR has perfect knowledge of the current SSB and no assessment is being performed. This is a limitation of running these projections and can be addressed by running a full MSE which can include an assessment stage to simulate the estimation of the perceived stock. The TAC is set as the total catch that will result from applying the desired F. If we are running an overcatch scenario extra catch will be added to this catch and the resulting 'true' F (i.e. the F that was realised, not the desired F) is calculated.

This is all put into a function which be called with the stock object that has been set up for projection:

```
project_hcr <- function(stock_proj, srr, overcatch, niters = 1000, nyears = 19,
    overcatch_flag = FALSE, zero_tac_flag = FALSE) {
    proj_years <- as.character(2013:range(stock_proj)["maxyear"])
    tac <- array(NA, dim = c(length(proj_years) + 1, niters), dimnames = list(year = c("2012",
        proj_years), iter = 1:niters))
    f_hcr <- tac
    tac["2012", ] <- tac_2012

    for (yr in proj_years) {
        cat("Year: ", yr, "\n")
        # Assume perfect knowledge of stock. obs. SSB = true SSB
        current_ssb <- c(ssb(stock_proj)[, yr])
        # if SSB < bpa, f = SSB*f01/bpa, else = f01
        target_f <- pmin(f01, current_ssb * (f01/bpa))
        # Implement Point 1, if SSB < 76kt, TAC = 0
        if (zero_tac_flag) {
            target_f[current_ssb < bclause1] <- 0
        }
        f_hcr[yr, ] <- target_f
        # Set up the control structure - really not easy
        ctrl <- fwdControl(data.frame(year = as.numeric(yr), val = target_f[1],
            quantity = "f"))
        ctrl@trgtArray <- array(NA, dim = c(1, 3, niters), dimnames = list(yr,
            c("min", "val", "max"), iter = 1:niters))
        ctrl@trgtArray[1, 2, ] <- target_f  # set the iterations
        # Project!
        stock_proj <- fwd(stock_proj, ctrl = ctrl, sr = srr)
        tac[yr, ] <- catch(stock_proj)[, yr]
```

```
        if (overcatch_flag) {
            # True catch is TAC + overcatch. Project forward with this catch to get
            # realised F.
            target_catch <- tac[yr, ] + overcatch[, yr]
            ctrl <- fwdControl(data.frame(year = as.numeric(yr), val = c(target_catch)[1],
                quantity = "catch"))
            ctrl@trgtArray <- array(NA, dim = c(1, 3, niters), dimnames = list(yr,
                c("min", "val", "max"), iter = 1:niters))
            ctrl@trgtArray[1, 2, ] <- c(target_catch)  # set the iterations
            stock_proj <- fwd(stock_proj, ctrl = ctrl, sr = srr)
        }
    }
    return(list(stock = stock_proj, f_hcr = f_hcr, tac = tac, oc = overcatch_flag,
        tac0 = zero_tac_flag))
}
```

2.6 Running the scenarios

As mentioned above, we are running different scenarios to explore different interpretations of the revised plan (whether to include overcatch, and whether the TAC can be set to zero). The HCR starts operating in 2013. Here are we are projecting from the end of 2011 for 19 years (until 2030).

```
nyears <- 19  # Project up to 2030
```

```
res <- list()
for (overcatch_flag in c(FALSE, TRUE)) for (zero_tac_flag in c(FALSE, TRUE)) {
    scen_name = paste("oc_", overcatch_flag, "_0tac_", zero_tac_flag, sep = "")
    # Make the stock for projection
    stock_proj_stuff <- make_stock_proj(stock, srr_iters, niters = niters, nyears = nyears,
        overcatch_flag = overcatch_flag)
    # HCR
    res[[scen_name]] <- project_hcr(stock_proj_stuff[["stock_proj"]], srr_iters,
        stock_proj_stuff[["overcatch"]], niters = niters, nyears = nyears, overcatch_flag = overcatch_f
        zero_tac_flag = zero_tac_flag)
}
```

We also run a constant F scenario where the HCR is not applied and the future fishing mortalities are constant. This represents a 'status quo' scenario. The constant levels are set as the mean of the last three years. This gives us a total of five scenarios (four 'HCR scenarios' and a constant F scenario) to compare.

```
meanf <- mean(fbar(stock)[, as.character(2009:2011)])
f_multiplier <- 1

target_f <- meanf * f_multiplier
stock_proj_stuff <- make_stock_proj(stock, srr_iters, niters = niters, nyears = nyears,
    overcatch_flag = FALSE)
ctrl <- fwdControl(data.frame(year = 2012:(2012 + nyears - 1), val = target_f,
    quantity = "f"))
stock_proj <- fwd(stock_proj_stuff[["stock_proj"]], ctrl = ctrl, sr = srr_iters)
res[["constant_f_current"]] <- list(stock = stock_proj, f_hcr = fbar(stock_proj)[,
    as.character(2012:(2012 + nyears - 1)), drop = TRUE], tac = catch(stock_proj)[,
    as.character(2012:(2012 + nyears - 1)), drop = TRUE], oc = FALSE, tac0 = FALSE)
```

3 Results

In line with the ToR, the performance of the plan is evaluated by its:

1. Compatibility with the Precautionary Approach (PA).
2. Ability to drive to management to this stock to MSY by 2015.

The performances of the five different scenarios are explored and compared.

In general, all of the scenarios (except the constant F scenario) showed a similar pattern of results with an eventual increase in SSB and catches and a stabilising of F around $F_{0.1}$. We first look at the differences between the scenarios, and then evaluate the performance in relation to the ToR. The main difference between the results from the different scenarios comes from the interpretation of Point 1. Due to the low SSB at the start of 2013, the TAC is set to zero if possible. This happens for two further years of the projections. This obviously results in zero catches in those years. However, this has the corresponding effect of promoting a faster increase in SSB and subsequent catches. This affects the compatibility with the PA, particularly when overcatches also occur.

The projections have been run to 2030. However, it should be noted that the predictive power of projections decrease as they go forward in time. The results upto 2020 should really only be considered as a qualitiative guide. The results after 2030 are included only to allow the SSB and catches to stabilise.

3.1 Impact of allowing TAC to be zero

As mentioned above, Point 1 of the revised plan can be interpreted to mean that the TAC may be set to zero if necessary and this is included in two of the scenarios. The impact of allowing the TAC to be zero can be seen in Figure 4 which compares results when there are overcatches.

The HCR starts operating in 2013. If the HCR allows the TAC to be set to zero this option is taken immediately and the fishery is effectively closed from 2013. The realised F and catch are reduced to very low levels until 2015 and the fishery reopens in 2016 (they are above zero due to the presence of overcatches). If the TAC is not allowed to be set to zero, Point 2.b. of the plan is implemented and F is reduced accordingly. When the TAC is zero, the strong reduction in fishing pressure results in a faster increase in SSB (and therefore recruitment) than when the TAC is not allowed to be zero. This means that when the fishery reopens in 2016, higher Fs and higher catches are realised than when the fishery was not closed.

Given that the stock is being managed to a target F, the long term 'equilibrium' catch and SSB will be the same whether the TAC is allowed to be zero or not ('equilibrium' is in quotes because the projections are stochastic). It is of interest that in the scenarios where the TAC can be zero, the time taken for the catch and SSB to reach 'equilibrium' is slightly reduced (this can be seen in the values for catch and SSB in Table 2).

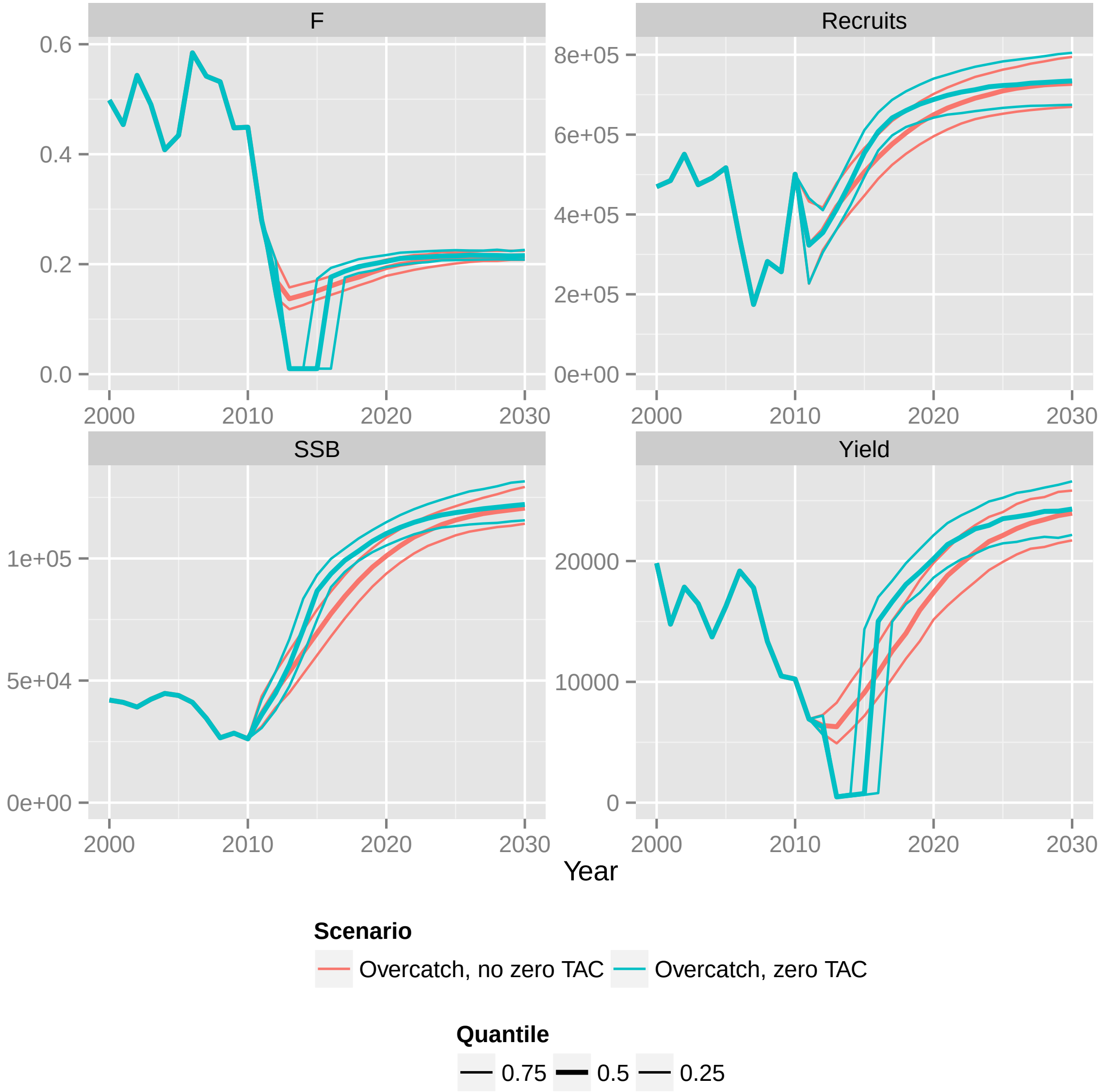

Figure 4: Comparing the performance of the zero TAC scenarios when overcatches are allowed

3.2 Impact of overcatches

The presence of overcatches, where the actual catch is greater than the TAC, increases the realised F so that it is above the target F set by the HCR. The difference between the scenarios with and without overcatch can be seen in Figure 5 which compares the results when a zero TAC is not allowed.

As expected, with overcatch the total actual catch is initially higher than when the actual catch is equal to the TAC. However, this difference gets smaller with time until the scenario without overcatch eventually results in slightly higher catches (by about 2020). This is because the SSB recovers faster and to a higher level when there is no overcatch. However, it is important to note that the level of overcatch is not proportional to the TAC, and has been predefined using a mean and standard deviation calculated from the last ten years of data (STECF, 2012). This means that as the total catch increases, the proportion of the total catch that comes from overcatch decreases.

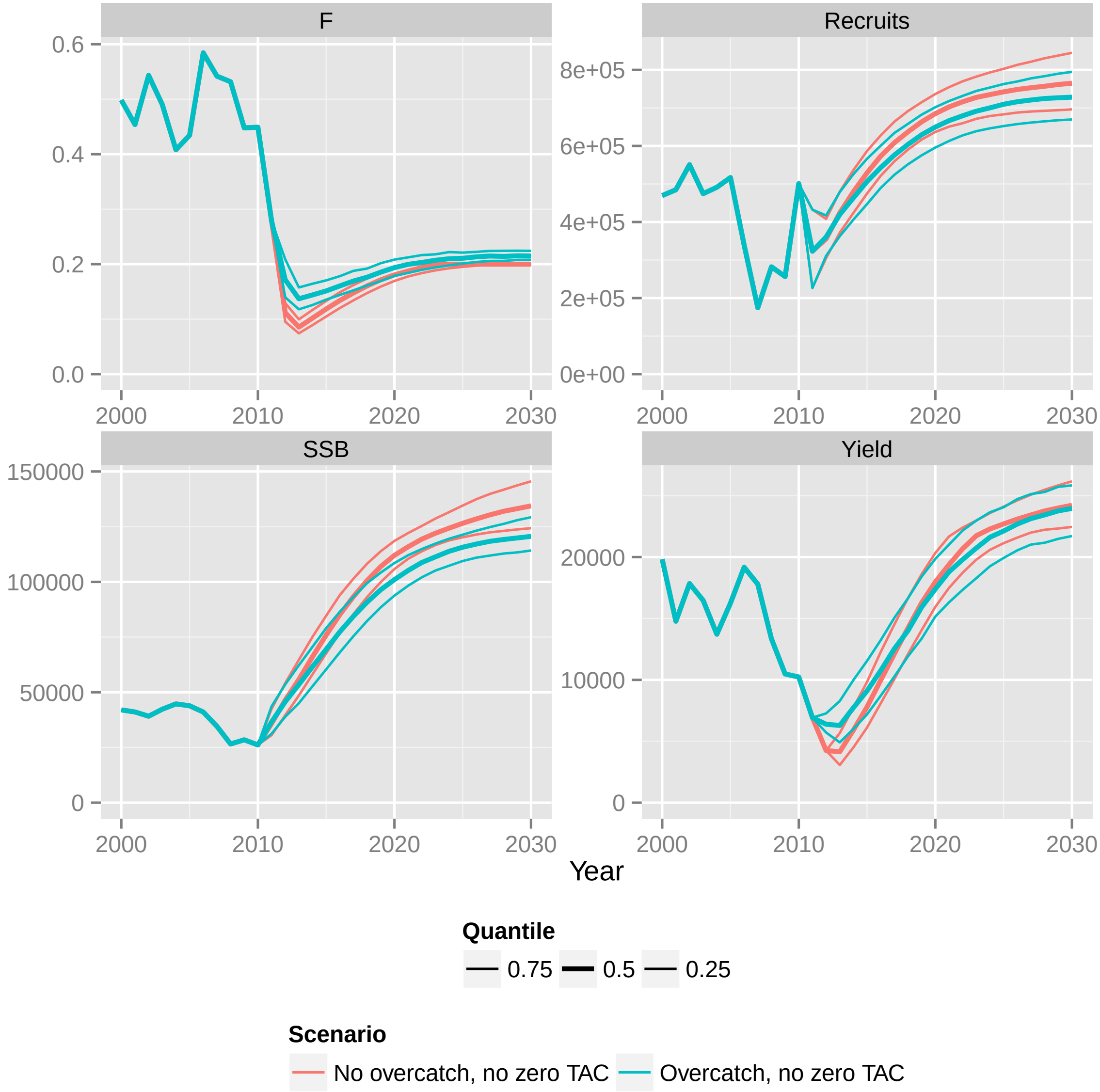

Figure 5: Comparing the overcatches scenarios when the zero TAC option is not allowed

3.3 Compatibility with the Precautionary Approach

To assess the compatibility with the PA we compare the projected SSB to B_{pa} (1.1×10^5) through time. As the simulations are stochastic, we calculate the probability of SSB being less than B_{pa} as a measure of risk (Figure 6).

There is a high probability ($\geq 96\%$) that all scenarios will result in SSB being below B_{pa} by 2015. This is because 2013 is the first year that the HCR is applied giving insufficient time for the stock to grow by 2015, even if a zero TAC is set (see Figures 4 and 5). By 2020 the probability has dropped to less than 50% for three of the HCR scenarios. The scenario where a zero TAC was not allowed and there are overcatches has a probability of 79% that SSB will be below B_{pa}. The most precautionary scenario is the one without overcatches and where a zero TAC is allowed to be set. For the constant F scenario, there is a 100% probability that the SSB will be below B_{pa} for the duration of the simulations.

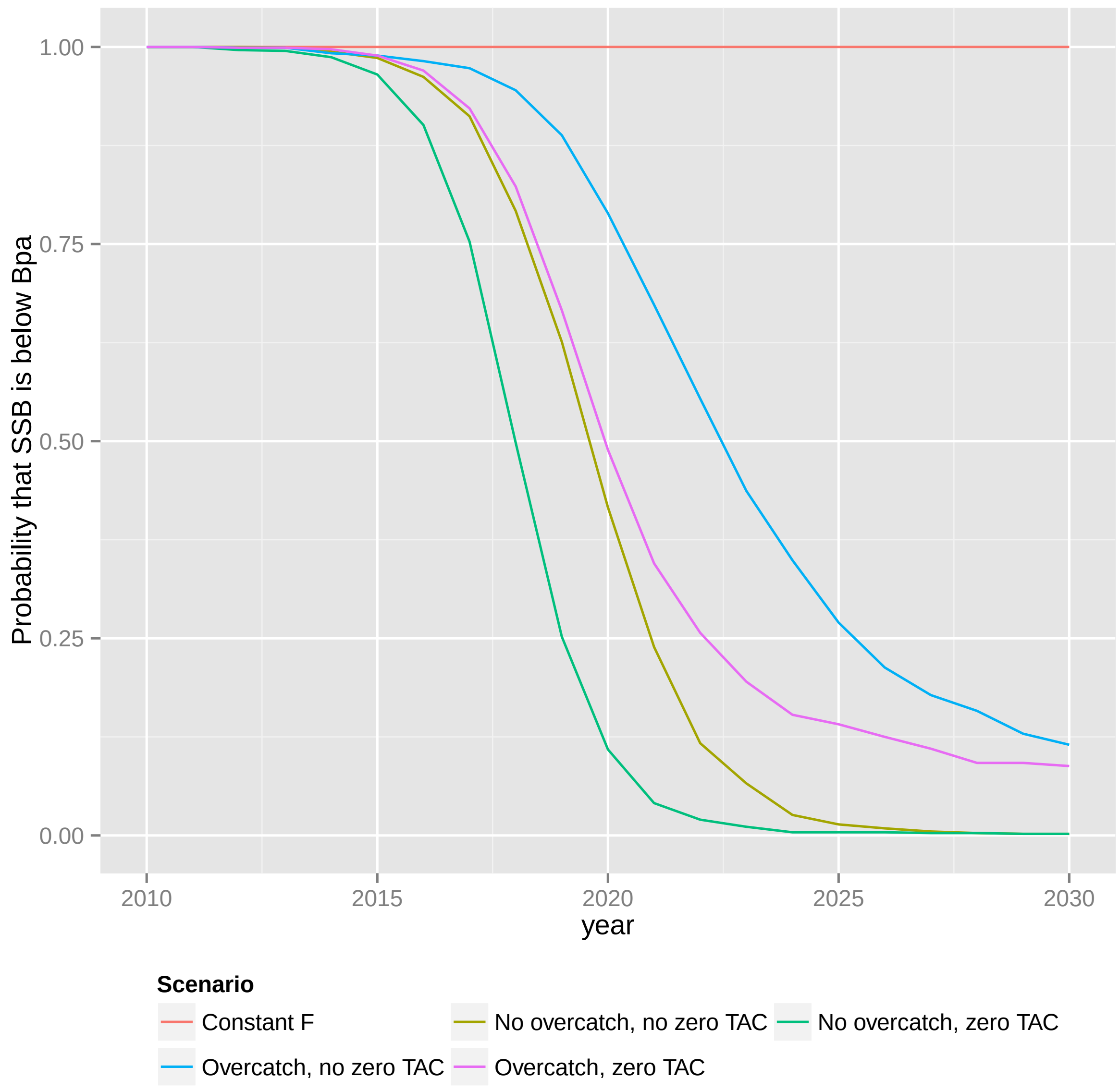

Figure 6: The probability of SSB being less than B_{pa}, i.e. assessing the compatibility with the Precautionary Approach.

3.4 Management to MSY by 2015

MSY and B_{msy} have not been defined for this stock so we are not able to evaluate whether the stock is managed to MSY in terms of catches or biomass. F_{msy} has been set at 0.25 (ICES, 2012). In the projections, a target F is set using Point 2. However, when overcatching occurs the realised F may be higher than the target F. We calculate the probability that the realised F is greater than F_{msy} for all of the scenarios (Figure 7).

The maximum fishing mortality that can be set by the HCR is $F_{0.1} = 0.2$ i.e. below F_{msy}. This means that without overcatch (i.e the TAC set by the HCR is implemented without error), the realised F is at most 0.2. For the HCR scenarios that have no overcatch, F is reduced to less than F_{msy} immediately and with 100% probability. When there is overcatch, the probability that the realised F is greater than F_{msy} is small (less than 10%). This means that even when there is overcatch, and the realised F is greater than that set by the HCR, the margin between aiming for $F = F_{0.1}$ and F_{msy} is sufficient to ensure that the realised F is very likely less than F_{msy}.

The scenario with constant F has a fixed F of 0.3921. The probability of realised F being above F_{msy} is therefore 100%

Even though the projections show that the stock is managed to F_{msy} by 2015, given the time it takes for the stock to respond to changes in fishing pressure, it does not mean that the stock abundances or catches will achieve MSY levels in a similar time frame. For example, it can be seen in Figures 4 and 5 that even though F does not exceed F_{msy} it still takes until about 2025 before the stock abundances and catches settle down regardless of the scenario. To further evaluate the management of the stock to MSY levels it will be necessary to define catch and / or abundance MSY values.

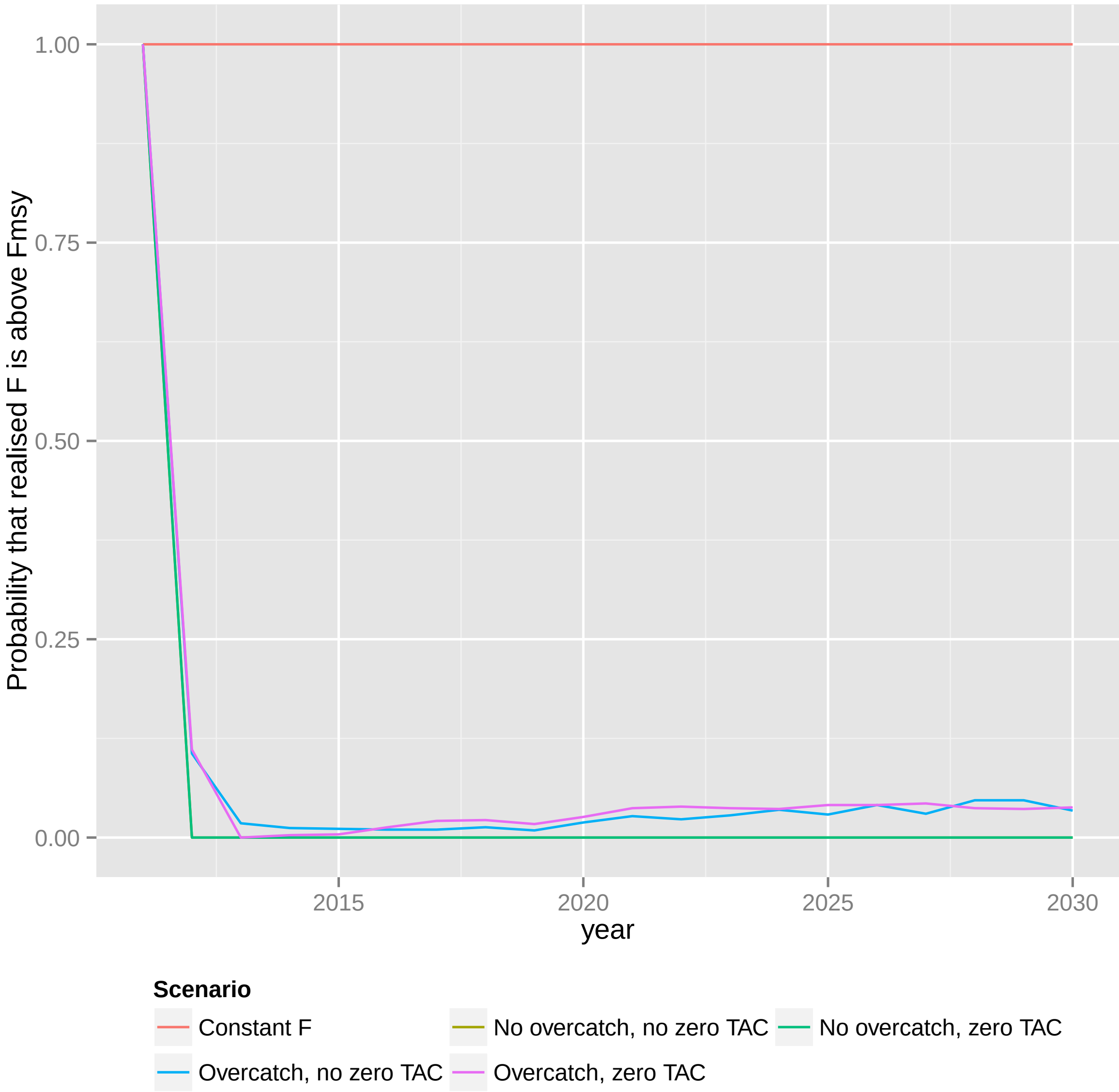

Figure 7: The probability that the realised F is greater than F_{msy}

3.5 Summary tables

A summary of the results relating to the ToR can be seen in Table 1. This looks at the probabilities of each scenario being compatible with the PA by 2015 and of being managed to MSY by 2015. A summary of the SSB and catches for each scenario in 2015 and 2020 is presented in Table 2.

Scenario	Probability SSB < Bpa (2020)	Probability F > Fmsy (2015)
Constant F	1.00	0.00
No overcatch, no zero TAC	0.42	0.00
No overcatch, zero TAC	0.11	0.00
Overcatch, no zero TAC	0.79	0.00
Overcatch, zero TAC	0.49	0.00

Table 1: Summary of compatibility with the Precautionary Approach (2020) and management to MSY (2015) for each scenario

Scenario	Med. catch (2015)	SD catch (2015)	Med. catch (2020)	SD catch (2020)	Med. SSB (2015)	SD SSB (2015)	Med. SSB (2020)	SD SSB (2020)
Constant F	13830	3294	14834	3115	41579	9449	44359	9358
No overcatch, no zero TAC	7804	3118	17977	3028	75907	13256	112040	10033
No overcatch, zero TAC	0	7111	20179	2307	90223	12930	118159	8580
Overcatch, no zero TAC	9108	3496	17401	3710	69454	14500	101035	11778
Overcatch, zero TAC	759	7511	20193	2698	86678	13078	110206	7380

Table 2: Median and standard deviation of catches and SSB in 2015 and 2020 for each scenario

4 Conclusions

Medium term stochastic projections were performed for five scenarios. Four of the scenarios used a HCR based on interpretations of the revised managment plan. A fifth scenario used a constant level of fishing mortality.

All of the HCR scenarios result in a decrease in F which ultimately stabilises to around $F_{0.1}$. This results in a corresponding increase in SSB and catches. If the HCR allows the TAC to be set to zero (Point 1 in the plan) then this option is taken and the fishery is effectively shut until 2016. This closure then results in higher SSB and higher catches when the fishery reopens.

Despite the immediate decrease in F, SSB is slow to increase. The rate of increase is partly determined by the SRR. This affects the compatibility of the plan with the PA. The chances of the SSB being above B_{pa} by 2015 for any of the HCR scenarios is very small ($< 4\%$). By 2020 the situation has improved and three of the four HCR scenarios have probabilities $> 50\%$ of the SSB being above B_{pa}. However, for the scenario where overcatches are present and the TAC is not allowed to be set to zero, the probability is only 21%. Although this scenario can be considered as the 'worst case' of the four HCR scenarios, it is still plausible.

All of the HCR scenarios have a high probability of maintaining F below F_{msy} by 2015. However, this does not take into account the time taken for the stocks to respond to the change in management. In the projections presented here, the biomasses and catches do not settle down until about 2025. To further evaluate the management of the stock to MSY levels it will be necessary to define catch and / or abundance MSY values.

The constant F scenario is included as example of maintaining the current status quo. This scenario performs worse than all of the four HCR scenarios. It is neither precautionary nor able to manage to MSY.

The medium term projections presented here have some serious limitations which need to be considered when evaluating the results. Perhaps most importantly, there is no stock assessment stage and the HCR operates with perfect knowledge of the true stock status. The response of fishers to the management plan has also not been considered, something that was recommended in the STECF report (STECF, 2012). Additionally, the initial stock abundances are taken from an exploratory assessment. As such, the results presented here should be considered as exploratory only. To help overcome some of these limitations an MSE should be peformed in line with the recommendations in STECF 2012 autumn plenary meeting.

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Abstract

DG MARE requested that STECF evaluate the proposed management plan of herring in VIaS and VIIbc as part of the plenary meeting 13-01. The first Term of Reference was to assess the plan for compatibility with the Precautionary Approach and its ability to manage the stock to MSY by 2015. This was investigated using stochastic medium term forecasts, the methods and results of which are presented here. As noted in the STECF 2012 autumn plenary meeting, some points of the revised plan require clarification with the Pelagic RAC. The simulations were performed under several assumptions and with different scenarios: whether there continue to be overcatches (i.e. the total catch is greater than the TAC) and whether the TAC is allowed to be set to zero if the SSB falls below 76 kt.

The results suggest that the plan is able to maintain fishing mortality at levels below \$F_{msy}\$. However, the ability of the plan to allow the SSB to recover above \$B_{pa}\$ depends on the level of overcatch (catch above the TAC) and whether the plan is allowed to reduce the TAC to zero if necessary. It is considered very unlikely that the SSB will recover to be above \$B_{pa}\$ by 2015 for any of the scenarios evaluated. By 2020 the probability that SSB will be below \$B_{pa}\$ ranges from 11 to 79\% depending on the scenario. The least precautionary scenario is where overcatches continue and the TAC is not allowed to be set to zero.

Given the time available, it was not possible to execute all of the suggestions made by STECF during the 2012 autumn plenary meeting regarding a full evaluation of the revised plan. These forecasts are not equivalent to a full evaluation. For example, in the simulations no assessment is performed and the plan is executed assuming perfect knowledge of the stock status. This means that the results of the simulations should only be considered as exploratory..

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